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# A TRANSCEIVER

Graham Alexander Munro MURDOCH
Annandale, New South Wales 2038,
AUSTRALIA

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I, KIM MARSHALL, MANAGER EXAMINATION SUPPORT AND SALES, hereby certify that the annexed is a true copy of the Provisional specification in connection with Application No. PP 1730 for a patent by PARAKAN PTY LTD filed on 9 February 1998.

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KIM MARSHALL
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# AUSTRALIA

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**PATENTS ACT 1990**

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# PROVISIONAL SPECIFICATION

***FOR THE INVENTION ENTITLED:-***

"A TRANSCEIVER"

The invention is described in the following statement:-

## FIELD OF INVENTION

The present invention relates to a transceiver.

The invention has been developed primarily for the field of Radio Frequency Identification (RFID) and will be described hereinafter with reference to that application. It will be appreciated, however that the invention is also applicable to other fields.

More particularly, the invention is applicable to receiving and transmitting data to and from a transponder using a single antenna, where the transmission may occur at any number of distinct frequencies. The invention has particular merit when applied to passive transponders. That is, transponders which derive their operating power from the received excitation or interrogation signal.

## BACKGROUND OF THE INVENTION

In prior art systems an RFID transponder includes a receiving antenna and a transmitting antenna. The need for separate antennae adds both to the cost and complexity of the transponder. To over come this limitation a number of single antenna transponders have been developed.

However, to receive signals with high efficiency a high Q antenna is required. Conversely, to transmit data at a high speed a low efficiency low Q antenna is required. This contradiction precludes the use of a high efficiency antenna for high speed data transmission. Additionally, in passive transponders the electrical inertia of the power storage system limits the data rate. Examples of such prior art systems are described in AU-A-55902/86, US 4,546,241, US 4,517,563, US 4,075,632, US 4,038,653, US 3,832,530 and US 3,299,424.

OBJECT OF THE INVENTION

It is an object of the invention, at least in the preferred embodiment, to overcome or substantially ameliorate one or more of these deficiencies of the prior art.

SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided a transceiver including:

an antenna for receiving a first signal and transmitting a second signal;

signal processor means for receiving from the antenna a third signal indicative of the first signal; and

modulator means disposed between the antenna and the signal processor means for providing a fourth signal to the antenna for forming the second signal, the modulator means varying the impedance between the antenna and the signal processor means for providing the antenna with a dual Q factor, the Q factor being high for the first signal and low for the second signal.

According to a second aspect of the invention there is provided a method for operating a transceiver including the steps of:

providing an antenna for receiving a first signal and transmitting a second signal;

providing signal processor means for receiving from the antenna a third signal indicative of the first signal;

providing a fourth signal to the antenna for forming the second signal; and

varying the impedance between the antenna and signal processor means for providing the antenna with a dual Q factor, the Q factor being high for the first signal and low for the second signal.

Preferably, the transceiver is a transponder and the first and second signals are modulated at a first frequency and a second frequency, wherein the first and second frequencies are different. More preferably, the transponder is passive and the signal processor means includes processing circuitry and power storage means, wherein some of the power provided by the third signal is stored in the power storage means for subsequently powering the transponder.

Preferably also, the modulator means varies the impedance between the antenna and the signal processor means between a high and a low value to effect a high and a low Q factor for signals respectively received by and transmitted from the antenna. Even more preferably, the impedance is varied between the high and the low value at a rate greater than the DC slew rate for the third signal. Most preferably, the impedance is a resistance.

In a preferred form the antenna is a coil which may be tuned by a capacitor. To transmit a signal from this type of single antenna the voltage across the antenna needs to be modulated or varied in some predetermined manner. Varying the antenna voltage corresponds to a proportional variation in the antenna coil current. That is, $d(I)=d(V)wL$. Prior art systems vary the antenna voltage by varying a parallel load across the antenna. In the preferred embodiment of this invention, however, the modulator means varies a low impedance which is disposed in series between the antenna and the signal processor means to cause a variation in the voltage across the antenna. More preferably, the low impedance is less than 10% of the total load impedance seen by the antenna.

In the preferred embodiment the series resistance is modulated with an RF sub-carrier and data is modulated onto the sub-carrier for transmission. Varying or modulating the value of this resistance causes rapid changes in the antenna voltage (and hence current) that are not limited by the antenna Q factor or by the storage means. In such a system the antenna simultaneously has a high Q to receive power and a low Q to transmit data. Furthermore, the inertia of the storage means acts to aid the imposition of high speed data onto the antenna. This preferred embodiment of the invention removes the limitation upon the data rate imposed by the storage means in passive transponders. The particular circuitry described allows the transmission rate of data to be decoupled from the Q factor of the antenna and the capacity of the DC storage means.

According to a third aspect of the invention there is provided a passive transponder including:

an antenna for receiving and transmitting a first signal and a second signal respectively;

signal processor means for receiving a third signal from the antenna which is derived from the first signal, the signal processor means also providing a fourth signal derived from the third signal;

power storage means in parallel with the signal processor means for absorbing some of the power of the third signal, the absorbed power being subsequently used by the transponder;

modulator means disposed between the antenna and the power storage means for selectively varying the impedance therebetween; and

a mixer for producing a fifth signal by combining the fourth signal with a sub-carrier, the fifth signal being provided to the modulator means.

Preferably, the modulator means varies the impedance in accordance with the fifth signal. More preferably, the impedance is a resistance.

In a preferred form the power storage means is a capacitor.

According to a fourth aspect of the invention there is provided an antenna for receiving and transmitting a first signal and a second signal respectively, these antenna including:

a turned coil in which the first signal generates a first current and which supports a second current for generating said second signal; and

modulator means through which said first and second currents flow for providing said coil with a dual Q factor, the Q factor being high for the first current and low for the second current.

Preferably, the first current is provided to the signal processing means. More preferably, the modulator varies the impedance between the coil and the processor means. Even more preferably, the impedance is a resistance which is switched between a predetermined value and zero resistance.

According to a fifth aspect of the invention there is provided a transceiver including:

an antenna for receiving a first signal and transmitting a second signal;

signal processor means for receiving from the antenna a third signal indicative of the first signal; and

modulator means disposed between the antenna and the signal processor means for providing a fourth signal to the antenna for forming the second signal, the modulator means varying the voltage across the antenna in a stepwise manner to effect a variation in the current flowing through the antenna between a low and a high value for allowing transmission of the second signal without affecting the receiving efficiency of the antenna.

According to another aspect of the invention there is provided a method for operating a transceiver including the steps of:

providing an antenna for receiving a first signal and transmitting a second signal;

providing signal processor means for receiving from the antenna a third signal indicative of the first signal;

providing a fourth signal to the antenna for forming the second signal; and

varying the voltage across the antenna in a stepwise manner to effect a variation in the current flowing through the antenna between a low and a high value for allowing transmission of the second signal without effecting the receiving efficiency of the antenna.

Preferably, first signal includes a carrier signal and the variation of the current between the low and the high value occurs within less than or about one period of the carrier signal.

DRAWINGS

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a prior art transponder circuit;

Figure 2 is a schematic representation of an AC electrical model for a tuned coil;

Figure 3 is a schematic representation of the electrical model for the prior art transponder circuit of Figure 1;

Figures 4(a) to 4(d) show the two mechanisms, with their associated waveforms, that limit the transient response of the prior art passive transponder antenna circuits;

Figures 5(a) and 5(b) are schematic representations of two embodiments of the invention where the modulator means includes a modulated resistance in the AC and DC part of the antenna circuit respectively;

Figures 6(a) and 6(b) are schematic representations of electrical models for the invention when the modulator switch SW1 is closed;

Figures 7(a) and 7(b) are schematic representations of electrical models for the invention when the modulator switch SW1 is open;

Figures 8(a) and 8(b) are schematic representations of two other embodiments of the invention where the series resistance is modulated by an RF sub-carrier in the AC and DC part of the antenna circuit respectively;

Figures 9(a) and 9(b) are schematic representations of two additional embodiments of the invention where the sub-carrier is modulated with data in the AC and DC part of the circuit respectively;

Figure 10(a) illustrates the switch function utilised by the invention;

Figure 10(b) illustrates the antenna voltage;

Figure 10(c) illustrates the frequency spectrum of the sub-carrier;

Figure 10(d) illustrates the frequency spectrum of the sub-carrier side bands;

Figure 10(e), (f) and (g) illustrate the frequency spectrum associated with the data modulated onto the sub-carrier;

Figures 11(a) and 11(b) are schematic representations of two other embodiments of the invention where the antenna is an untuned coil and the series resistance is modulated by an RF sub-carrier in the AC and DC part of the antenna circuit respectively;

Figures 12(a) to 12(d) are schematic representations of four alternative arrangements for modulating the series resistance: and

Figures 13(a), 13(b) and 14 are schematic representations of the transceiver according to the invention shown in terms of the Compensation Theorem.

PREFERRED EMBODIMENTS OF THE INVENTION

In the following explanation of the preferred embodiments of the invention there is description of both time and frequency domain methods. As will be appreciated by those skilled in the art, the frequency domain methods are primarily used to interpret AC electrical models whilst the time domain methods primarily provide information on the transient behaviour of the invention.

RFID transponders that include a single antenna are selectively interrogated with an interrogating or exciting field. This field is received by the antenna and a voltage induced. This voltage is then rectified and used to power the transponder. Moreover, the transponder also transmits messages back to its interrogator using the same antenna. In prior art systems a resistance is placed in parallel with the antenna and modulated to change the antenna current and thereby generate the transmitted signal.

Figure 1 shows such a prior art system having a tuned antenna coil L. Located in parallel with the tuned coil is a resistance R(modulator) which is switched to provide the desired antenna response. The AC signal produced by the antenna is passed to a rectifier and converted to a DC voltage which is stored on a DC storage capacitor Cdc. Typically, the rectifier uses a halfwave single rectifier circuit, although in other embodiments a fullwave bridge rectifier circuit or any other suitable rectifier configuration is used. An example of the latter is a voltage doubler. The transponder circuit load is represented by the load resistor R(chip).

Figure 2 shows a known AC electrical model for a tuned coil. The transient response of the coil is determined by the total Q factor (Qt) of the antenna circuit. In this example the following holds:

$$1/Qt = 1/Qc + 1/Qi \tag{1}$$

where Qc is the tuning capacitor Q factor (Qc = wRC) and Qi is the coil Q factor (Qi=wL/r). This circuit has a time constant Ts for either sinusoidal excitation or a component parametric change which is given by:

$$Ts = Qt.T/PI \tag{2}$$

where T is the period of the sinusoid.

Figure 3 shows the electrical model for the prior art circuit of Figure 1. The effective load of the signal processor circuitry on the antenna circuit is schematically shown by R(chip) and the modulation resistance is R(modulator). The antenna coil current Ia is given by:

$$Ia = 2.Vo.(wC).Rt \tag{3}$$

where Vo is the antenna terminal voltage, Rt is the total parallel resistance of R(modulator) and the effective AC load presented by R(chip). The DC load R(chip) presents an effective AC load of R(chip)/2.

The rate of change of current in the antenna is limited by two factors. First, the Q factor of the antenna limits the transient response time constant Ts. Second, the size of the transponder's DC power storage means (the DC storage capacitor). Any change in the antenna current will be matched by a commensurate change in the antenna voltage, which will eventually lead to a change in the DC voltage on the DC storage capacitor. As this represents a change in the energy stored in the DC system a finite time will be required for the antenna circuit to supply the change in energy.

Figures 4(a) to 4(d) schematically and graphically illustrate the two limiting mechanisms referred to above. In particular, Figures 4(a) and 4(b) show the antenna circuit with a resistive load, and the associated waveforms, respectively. In this configuration the Q factor of the antenna limits the transient response. Figure 4(c) and 4(d) show the antenna circuit with a large capacitive load, and its associated waveforms, respectively. In this latter configuration the antenna circuit is connected, via a rectifier, to a DC storage capacitor Cdc and parallel resistive load, where the transient response is limited by the size of the DC storage capacitor and the charging current available from the antenna. The DC current supplied to the load Ii is given by:

$$Ii = Vdc/R(chip) \qquad (4)$$

Therefore a change of d(Vdc) in the capacitor voltage will take a time of:

$$Tdc = d(Vdc).R(chip).Cdc/Vdc \qquad (5)$$

where Vdc is the DC output voltage. Particularly reference is made to Figure 4(d) which illustrates the quantity Tdc.

The invention has been developed in answer to these limitations, and illustrated schematically in Figures 5(a) and 5(b) are two preferred embodiments of the invention. In Figure 5(a) a modulated series resistor, in the form of resistor R(modulator) and parallel switch SW1, is placed between the antenna and the storage capacitor in the AC part of the circuit. In Figure 5(b) a modulated series resistor, again in the form of resistor R(modulator) and parallel switch SW1, is placed between the antenna and the storage capacitor in the DC part of the circuit Both circuits produce the same transmitted signal, although in practice the circuit shown in Figure 5(b) is preferred as it is simpler to implement due to its DC operating bias.

Switch SW1 represents some modulation means that varies the impedance of series resistor R(modulator). For simplicity a switch is shown although other means of achieving a controlled variable impedance are used in other embodiments. The switch is modulated with a data signal that can be either a baseband signal or a high frequency sub-carrier with data modulated on to the sub-carrier for transmission. Typically the sub-carrier frequency is in the range from 5% to 50% of the excitation frequency. Additionally, the preferred method of modulating the sub-carrier is Phase Reverse Keying (PRK).

The envelope of the voltage across the antenna follows the openings and closures of switch SW1. When the switch is closed the antenna voltage is clamped to the DC storage capacitor voltage through the low impedance of the rectifier.

Figures 6(a) and 6(b) show electrical models for the invention when the modulator switch SW1 is closed. In these circumstances the series impedance of the switch is reduced to a minimum (nominally zero). Figure 6(a) shows the antenna circuit with the rectifiers and the DC circuit. The residual series impedance between the antenna and the storage capacitor is that of the dynamic impedance of the rectifier. Accordingly, the following holds:

$$R(diode)=d(Vdiode)/d(Idiode) \qquad (6)$$

In this state the DC storage capacitor can be represented by a low impedance voltage source which provides a DC voltage of Vdc. The chip load is represented by R(chip). The average current from the DC storage capacitor must be zero for steady state operation and hence the average current flow in the representative voltage source is zero. Figure 6(b) shows the equivalent AC circuit model, where the DC storage impedance acts as an AC short circuit and the load impedance seen by the antenna is only the dynamic impedance of the rectifier. Since the AC impedance of the DC storage capacitor is very small it behaves as a short circuit in the AC circuit and as a low impedance voltage source for the DC circuit.

When switch SW1 is open, current pulses from the rectifier and charges the DC capacitor through R(modulator). Accordingly, an instantaneous voltage V(modulator,t) is produced, where:

$$V(modulator,t)=R(modulator).I(diode,t) \qquad (7)$$

It will be appreciated that I(diode,t) is the instantaneous rectifier current.

The peak antenna voltage is therefore fixed at the sum of the DC capacitor voltage and V(modulator,t) through the rectifier.

Figures 7(a) and 7(b) show electrical models for the invention when the modulator switch SW1 is open. In this configuration the series modulator impedance, as seen by the antenna, is increased to a maximum, nominally R(modulator). Figure 7(a) shows the antenna circuit with rectifiers and the DC circuit. The series impedance between the antenna and the storage capacitor is that of the dynamic impedance of the rectifier R(diode) and the modulation resistance R(modulator), where:

R(diode)=d(Vdiode)/d(Idiode) (8)

The DC storage capacitor can be represented by a low impedance voltage source with the DC voltage Vdc across it and the chip load is represented by R(chip). The average current from the DC storage capacitor must be zero for steady state operation and hence the average current flow in the representative voltage source is zero. Figure 7(b) shows the equivalent AC circuit model where the load impedance seen by the chip is the sum of the dynamic impedance of the rectifier and the modulation resistance R(modulator). Since the AC impedance of the DC storage capacitor is very small it is modelled as an AC short circuit.

At the operating frequency of the transponder the DC storage capacitor presents a low impedance to effectively decouple the DC rail. In effect, the capacitor presents a short circuit to the AC signals. Positioning R(modulator) between the antenna and the DC storage capacitor means that the antenna "looks" through this small resistance into the capacitor short circuit. Consequently the effective AC load on the antenna is only the sum of R(modulator) and R(diode). Accordingly, the total Q factor of the antenna (Qt) will be extremely small. In this embodiment typical values are R(diode)=120R, L=5uH

and C=27pF. This provides a total Q factor Qt=0.28. Hence the transient response of the antenna is no longer limited by its Q factor.

With changes in the series impedance of R(modulator) the steady state operating condition of the circuit can be expected to change with a commensurate change in the DC capacitor voltage. A change in operating DC voltage represent a change in the energy stored in this capacitor. The larger the capacitor value the greater the amount of energy required to change its voltage. In prior art systems the antenna voltage must track the DC voltage and the inertia of the DC storage system severely limits the maximum data rate. The maximum slew rate of the DC voltage, d(Vdc)/dt, is given as follows:

$$
\begin{aligned}
d(Vdc)/dt &= Cdc/Idc \\
&= Cdc.R(chip)/Vdc \qquad (9)
\end{aligned}
$$

This change will take on the order of tens of microseconds or longer. This explains the reason for the prior art limitation on data rate. More particularly, the prior art modulation switching rate had to be less than the DC slew rate limit. In contrast, this invention accommodates a modulation switch rate greater than this same limit.

The modulator switch SW1 is operated at a high frequency, spending only a fraction of its time (typically 50%) open and the balance closed. Consequently, the modulator resistor presents an average resistance (typically 50%) of its actual value to the circuit. As switch SW1 opens and closes the DC voltage across the capacitor Cdc remains essentially unchanged because of the decoupling action described above. Over time, however, the circuit will move to a new steady state operating point commensurate with this average resistance value. Accordingly, in these embodiments there is a lower

limit on the switch rate which must be faster than the response time of the DC capacitor voltage to the change in series impedance. An example of typical values of components are Cdc=10nF, R(modulator)=120R, Vdc=3.3V and Idc=1mA. These provide a slew rate of 10us which implies a minimum switch rate greater than 100KHz.

From this steady state condition closure of the switch will cause the DC storage capacitor to clamp the peak antenna voltage to Vdc. Conversely, opening the switch will increase the peak antenna voltage by V(modulator,t)=R(modulator).I(diode,t). The peak rectifier current, that is, MAX I(diode,t) is roughly eight to ten times the average DC load current. Therefore, the maximum modulator voltage MAXV(modulator,t) is given by:

$$\text{MAXV(modulator,t)}=8.\text{R(modulator)}.\text{Vdc}/\text{R(load)} \qquad (10)$$

For typical circuit values of Vdc=3.3V, R(load)=3K3R and R(modulator)=120R, then MAXV(modulator)=0.96V.

The dynamic load seen by the tuned circuit is the series resistance of R(modulator) and the rectifier dynamic impedance (typically R(diode)=1V/8mA=120R). Therefore R(modulator)+1V/8mA=240R. The DC storage capacitor is an effective AC short circuit. For typical values of L=5uH, C=27pF and R(modulator)+1V/8mA=240R then Qt=0.55. That is, the antenna's transient response is not be limited by its Q factor. In effect, the peak voltage across the antenna will instantaneously move to the new peak value.

Figures 8(a) and 8(b) show embodiments of the invention where the series resistance is modulated by an RF sub-carrier. The RF sub-carrier is amplitude modulated onto the antenna. Figure 9(a) and 9(b) show embodiments of the invention

where data is modulated onto the sub-carrier. Data imposed on the sub-carrier (as sub-carrier modulation) is then transmitted from the antenna. The preferred method of sub-carrier modulation is PRK because it does not produce any change in the circuit's DC operating point. The sub-carrier frequency can be derived from any source. In the preferred embodiment it is derived by division of the excitation field's frequency. Most preferably, however, The sub-carrier frequency is faster than the maximum slew rate of the DC storage system, where that slew rate in the present embodiment is given by:

$$d(Vdc)/dt=Cdc.R(chip)/Vdc \quad (11)$$

A wide range of sub-carrier frequencies is accommodated by this embodiment. For example, in one form the sub-carrier frequency is as high as 50% of the excitation frequency, while in other forms that sub-carrier frequency is as low as a few percent of the excitation frequency. As will be appreciated, the low frequency limit is effectively imposed by the DC storage capacitor slew rate.

Figures 10(a) to 10(g) show various voltage waveforms and spectra that provide further assistance in understanding the operation of the Figure 8 and 9 embodiments of the invention. As shown, the opening and closing of the modulator switch, the antenna voltage effectively instantaneously follows the switch action. The relationship between the switch closures and the antenna voltage is shown in Figures 10(a) and 10(b). The antenna voltage is amplitude modulated by the series impedance modulator at the sub-carrier frequency Fs. The spectrum of the antenna current will consist of the excitation frequency Fc and sidebands at Fc+Fs and Fc-Fs as shown in Figures 10(c) and 10(d). The sub-carrier has been frequency translated by amplitude modulation up to the excitation frequency. The sub-carrier may be modulated with data, preferentially PRK

because it does not disturb the DC operating point of the circuit. Figures 10(e) and 10(g) show the data spectrum modulated onto the sub-carrier which is then amplitude modulated onto the excitation frequency of the antenna.

The modulated sub-carrier sideband currents generate a field which radiates off the antenna. The sub-carrier frequency should be greater than the circuit's DC settling time so as not to disturb the steady state operating point. Preferably also, the sub-carrier frequency is less than the excitation frequency. In the preferred embodiment the sub-carrier is generated by dividing down the excitation frequency. A large number of sub-carrier frequencies are available through the judicious choice of divider values. Thus by randomly selecting a divider value from an available set of divider values the transponder can choose a channel to transmit data on and consequently is capable of simultaneously identifying itself amongst a multitude of similar transponders. Such an arrangement is disclosed in Australian patent application no. 00469/88, the disclosure of which is incorporated herein by way of cross reference.

Further to the advantage of being able to generate a high frequency carrier suitable for the transmission of data at high speeds, these sub-carriers are well away from the close to carrier phase noise in the excitation signal. Consequently, compared to the prior art systems, a receiver will be able to detect a much weaker transponder signal because the excitation signal's phase noise does not interfere with the transponder's signal.

Figures 11(a) and 11(b) show embodiments of the invention where the antenna is an untuned coil. In figure 11(a) a modulated series resistor is placed between the antenna and the storage capacitor in the AC part of the circuit. In Figure 11(b) a

modulated series resistor is placed between the antenna and the storage capacitor in the DC part of the circuit. Although both circuits produce the same transmitted signal the circuit of Figure 11(b) is simpler to implement because of the DC operating bias. Switch SW1 represents modulation means for varying the impedance of series resistor Rs. For simplicity a switch is shown although in other embodiments alternative methods of achieving a controlled variable impedance are used.

In embodiments where an untuned antenna is used the response rate is limited by the DC storage system only. Notwithstanding, the advantages of the series impedance modulator applied to tuned antennas still applies. The voltage across the modulation resistor V(modulator) is given by:

$$V(\text{modulator})=R(\text{modulator}).I(\text{diode}) \tag{12}$$

and is generated by the rectifier current. This voltage adds to the voltage across the DC storage capacitor, and the instantaneous peak coil voltage follows the switch openings and closures. Provided the switch rate is significantly faster than the DC slew rate then there will be no change in the circuits DC operating point and hence no change in the energy stored in the DC storage capacitor.

Figures 12(a) to 12(d) show various arrangement for modulating the series resistance. The switch shown in Figure 12(a) can be implemented by way of a FET or BJT switch as shown in Figure 12(b). Alternatively, the channel resistance of a FET can be used to create a specific switchable series resistance, and is illustrated in Figure 12(c). Figure 12(d) shows an arrangement where the value of the series resistance can be varied between two (or more) values.

The preferred embodiment of the invention will now be described in more general terms using the "Compensation Theorem". The Compensation Theorem is as follows:

> If the impedance of a branch carrying a current I is increased by $\Delta Z$ then the increment in current and voltage in each branch of the network is the same as would be produced by an opposing voltage $\Delta V = I\Delta Z$ introduced in series with $\Delta Z$ in the same branch.

A reference for this is given in "Electrical Engineering Circuits" 2nd edition H.H Skilling page 373.

For an antenna with a rectifier and DC storage means (capacitor) connected the peak antenna voltage is clamped through the rectifier to the DC storage voltage. In the prior art, changes in the antenna terminal peak voltage causes corresponding changes in the antenna current. This, however, can occur no faster than the rate with which the DC voltage can slew, as has been discussed above.

For modelling purposes the DC storage capacitor is replaced with a voltage source Vdc and the rectifiers with a fixed forward volt drop equal to V(diode). The peak antenna voltage will be clamped at Vdc+V(diode). If the voltage source Vdc experiences a small step change dVdc then the peak antenna voltage will instantly follow, since it is clamped to it through the rectifiers. That is, Vdc→Vdc+dVdc. Figure 13(a) shows an arrangement where the voltage source dVdc is in series with Vdc.

Alternatively the same behaviour occurs if two separate voltage sources are used. Figures 13(b) shows such an arrangement where Va=Vdc and Vb=Vdc+dVdc. This is equivalent to causing an instantaneous change to the DC storage voltage in the prior art

system. However, this is impossible in practice as it requires an infinite impulse of power.

The invention provides an alternative arrangement for achieving this same result by placing a voltage source in series with Vdc as shown in Figure 13(a). The effect of the modulator can be understood with reference to the Compensation Theorem. The modulator resistance R(modulator) with parallel switch closed is represented by a short circuit. When the switch opens the Compensation Theorem represents it as R(modulator) in series with a voltage source V(modulator)=I(diode).R(modulator). The transient response can then be fully described by considering this step voltage change V(modulator) in series with R(modulator) and the rectifier impedance. The DC voltage source Vdc is ignored. Since the antenna is being driven by a step applied voltage source through a low impedance the antenna will be instantly driven to the new peak voltage as per the circuits of Figures 13(a) and 13(b). Figure 14 shows the circuit where the equivalent Compensation Theorem derived source is connected to the antenna.

Although the invention has been described with reference to specific examples it will be appreciated by those skilled in the art that it may be embodied in many other forms.

DATED this 9th Day of February, 1998

PARAKAN PTY. LTD.

Attorney: JOHN B. REDFERN

Fellow Institute of Patent Attorneys of Australia

of SHELSTON WATERS

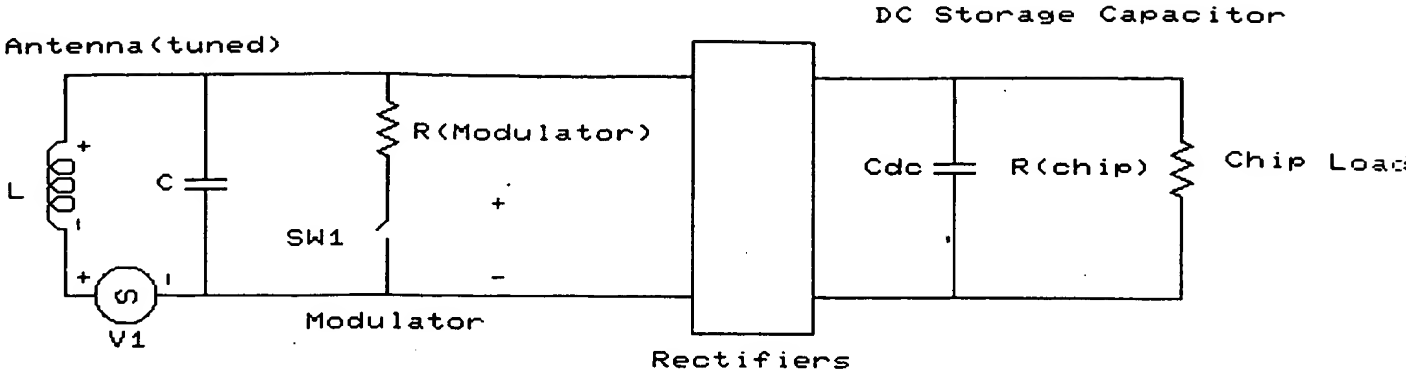
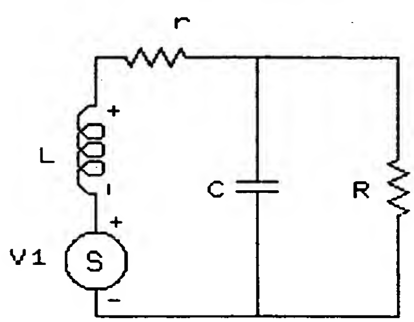



Figure 1 : Prior Art Transponder




$1/Qt=1/Qc+1/Qi$

$Qc=\omega RC \quad Qi=\omega L/r$

$1/R=1/R(modulator)+1/R(chip)/2$

Figure 2 : Tuned Circuit Model

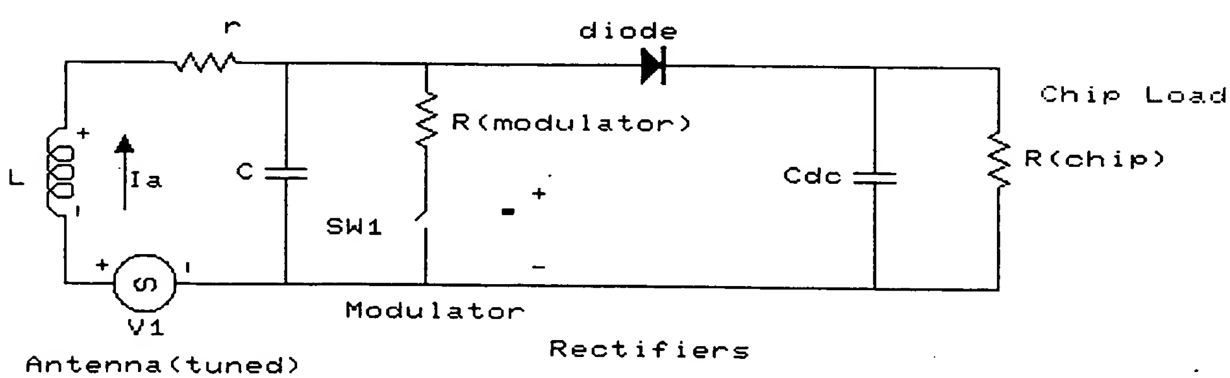



Figure 3 : Electrical Model for Prior Art Circuit

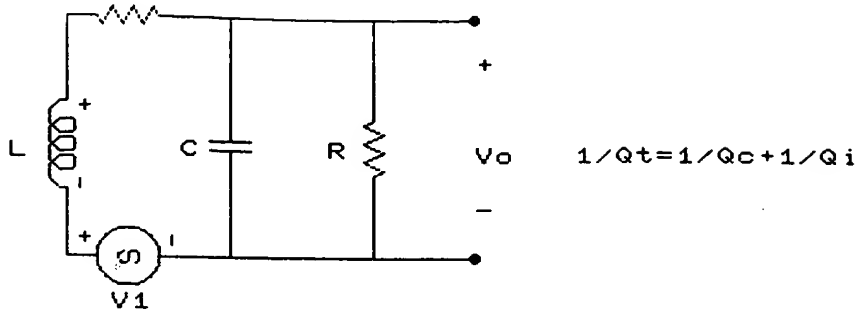



Figure 4(a) : Data Rate Limited due to Q factor

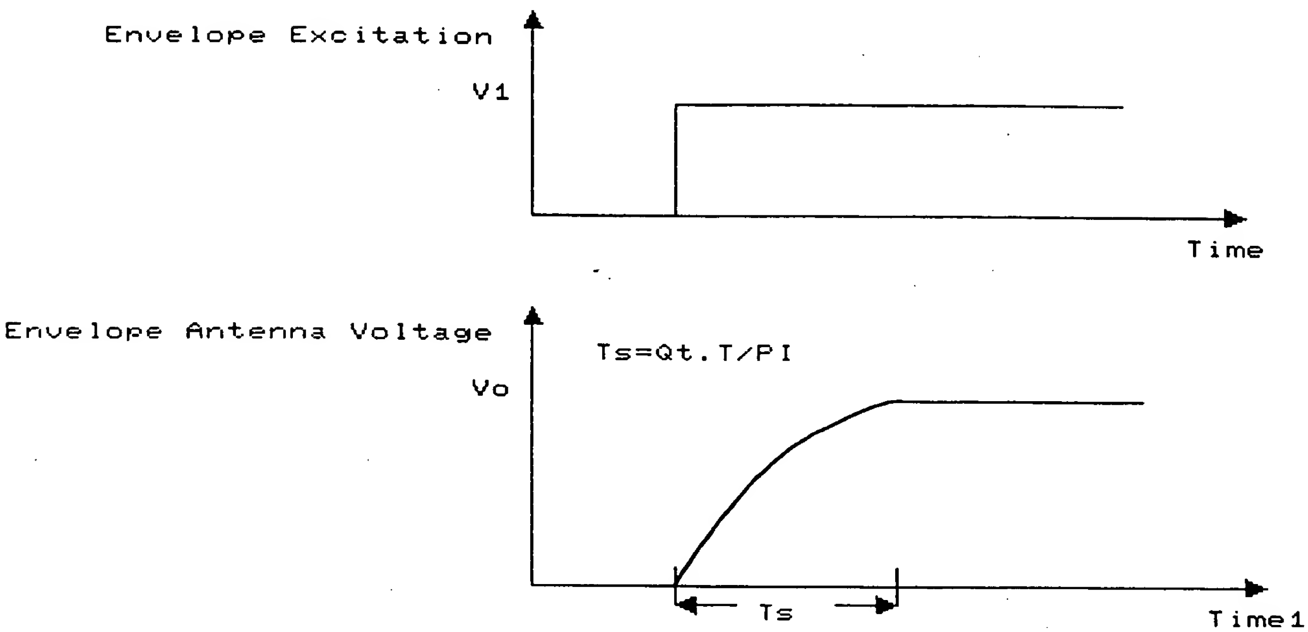



Figure 4(b) : Envelope of Waveform associated with Q factor

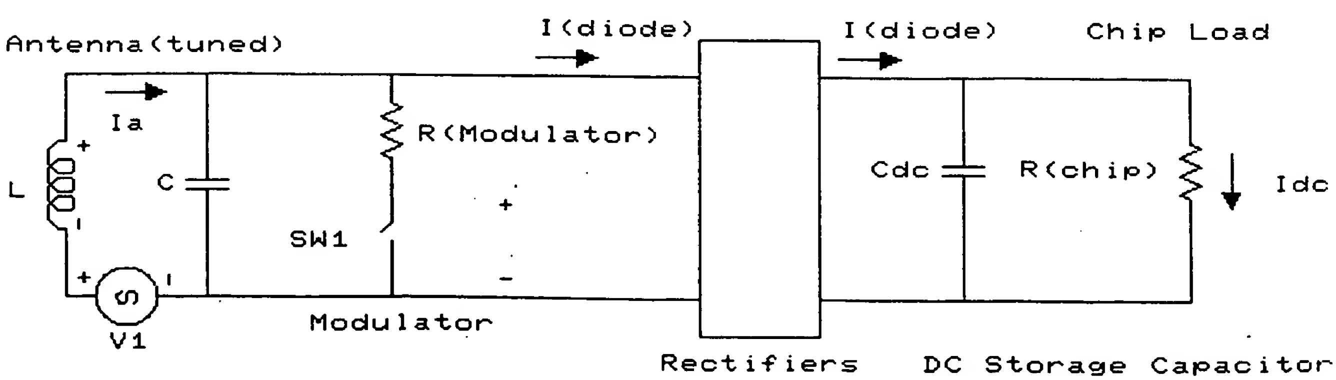



Figure 4(c) : Data Rate Limit due to DC Storage System

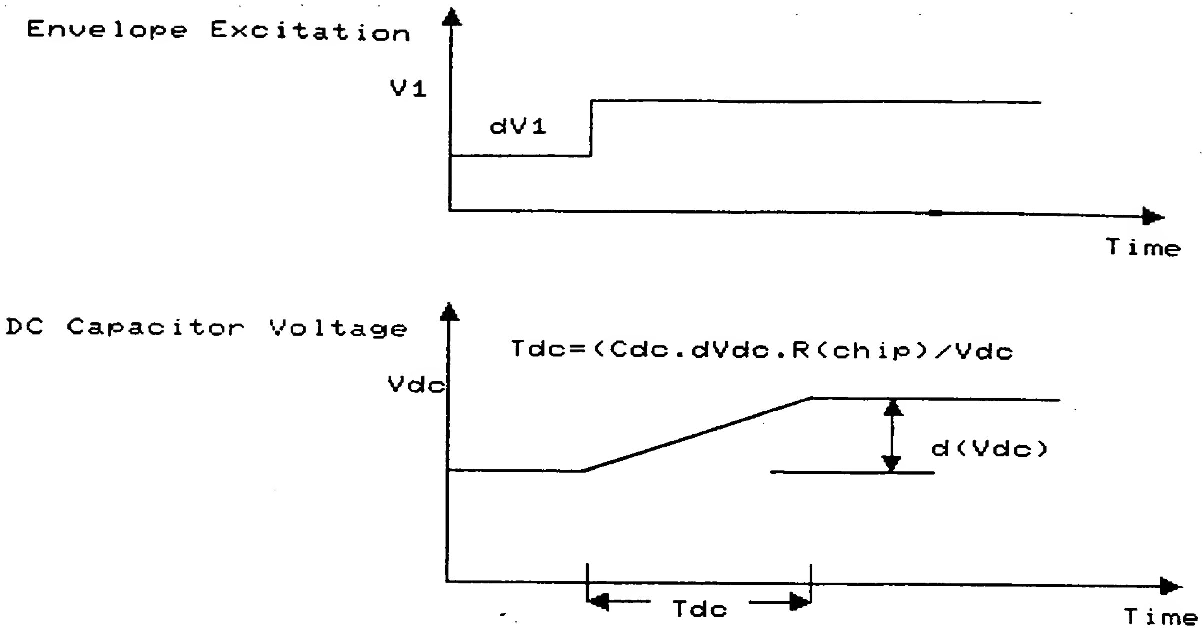



Figure 4(d) : DC Waveform associated with DC Storage Limit

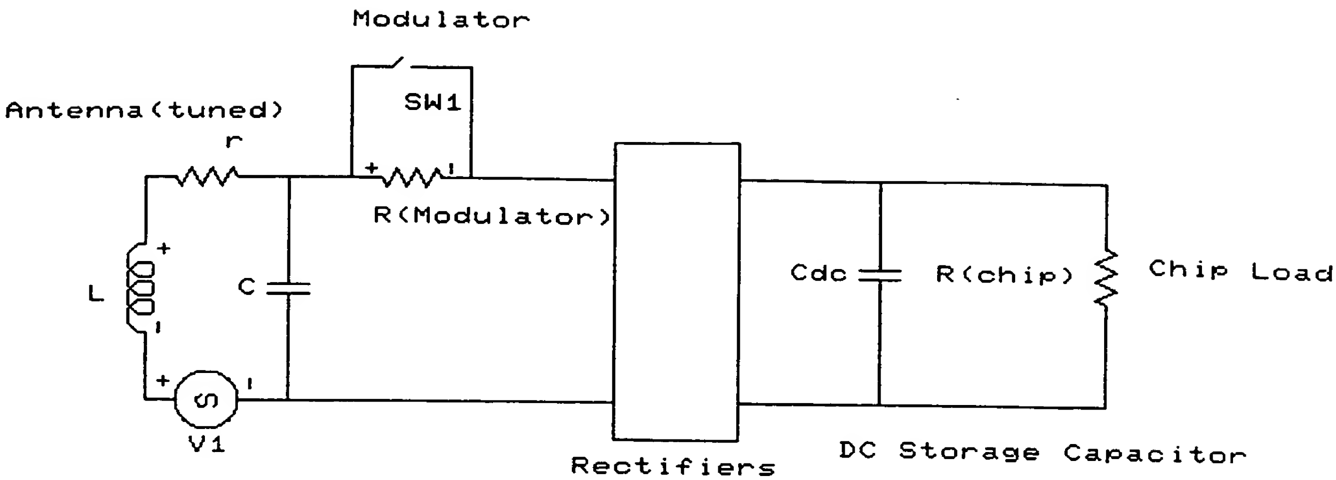



Figure 5(a) : Invention with Modulator in AC part of Circuit

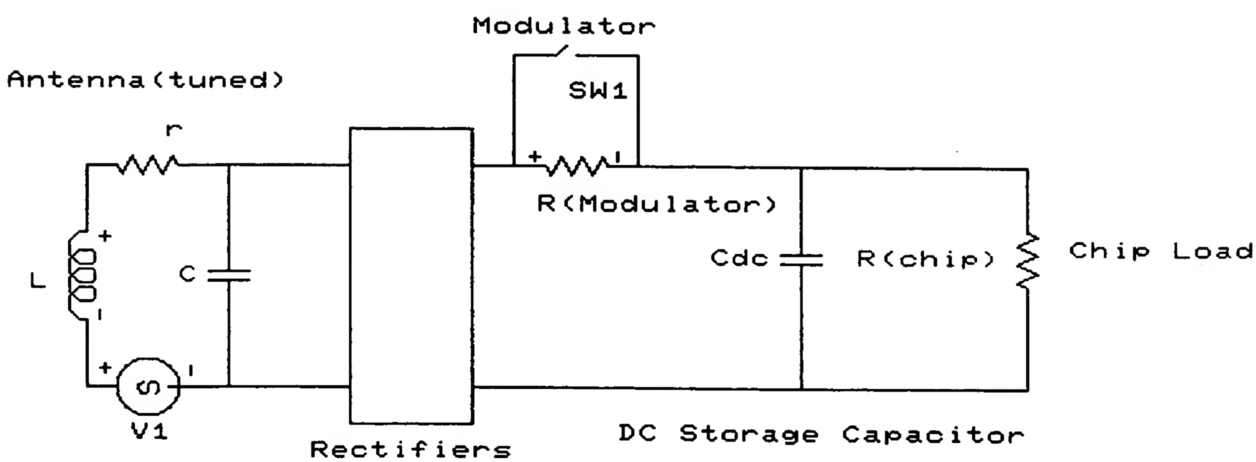



Figure 5(b) : Invention with Modulator in DC part of Circuit

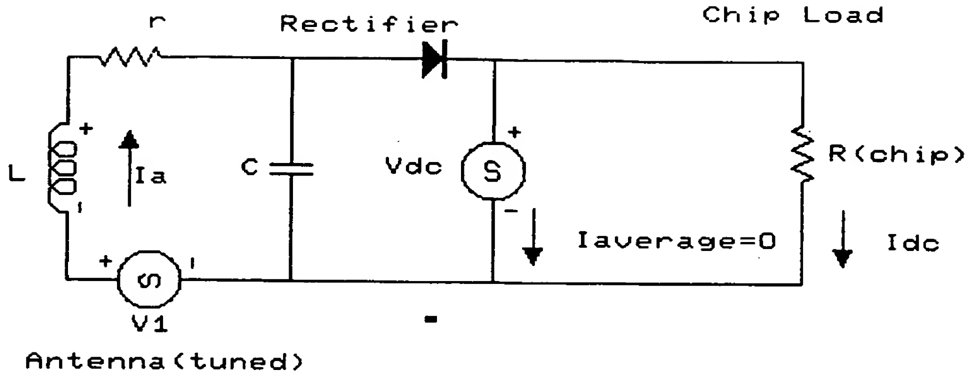



Figure 6(a) : Electrical Model for Invention with SW1 Closed

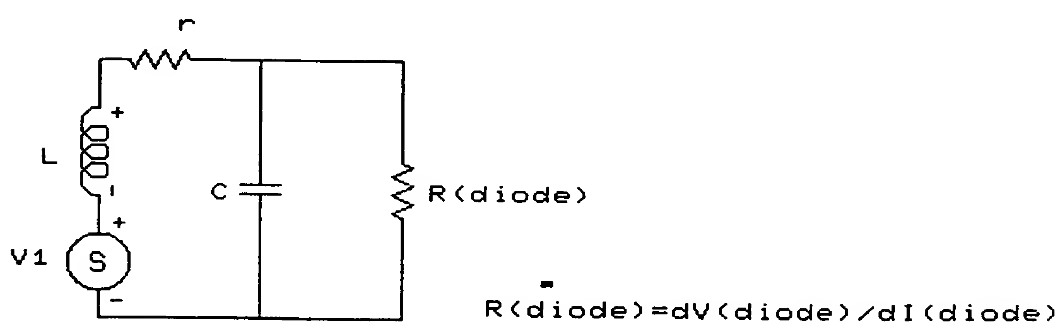



Figure 6(b) : Electrical Model for Invention with SW1 Closed

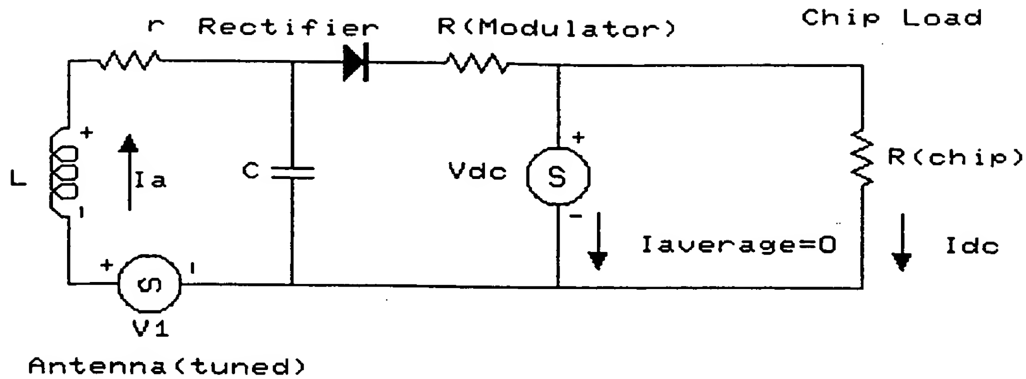



Figure 7(a) : Electrical Model for Invention with SW1 Open

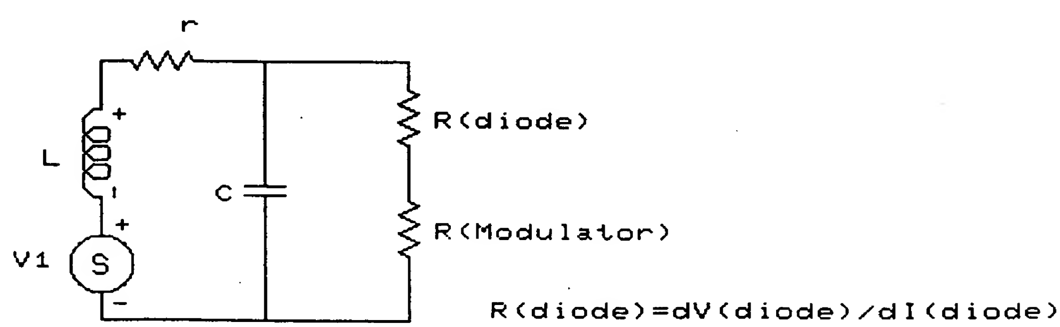



Figure 7(b) : Electrical Model for Invention with SW1 Open

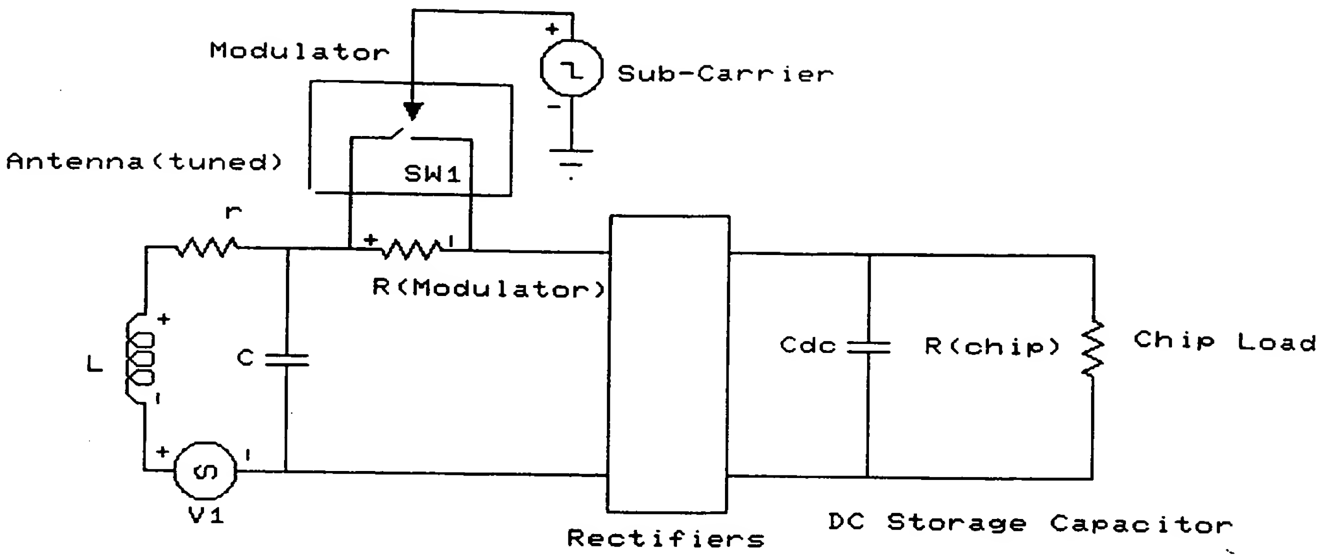



Figure 8(a) : Invention with Sub-Carrier Modulation of Modulator in AC Circuit

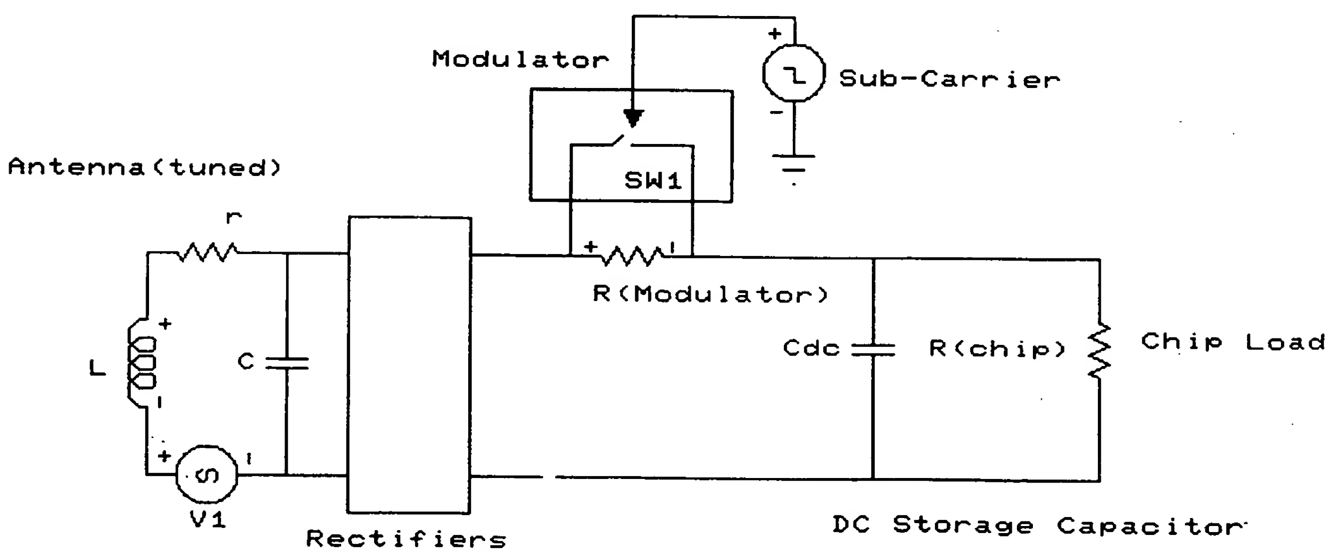



Figure 8(b) : Invention with Sub-Carrier Modulation of Modulator in DC Circuit

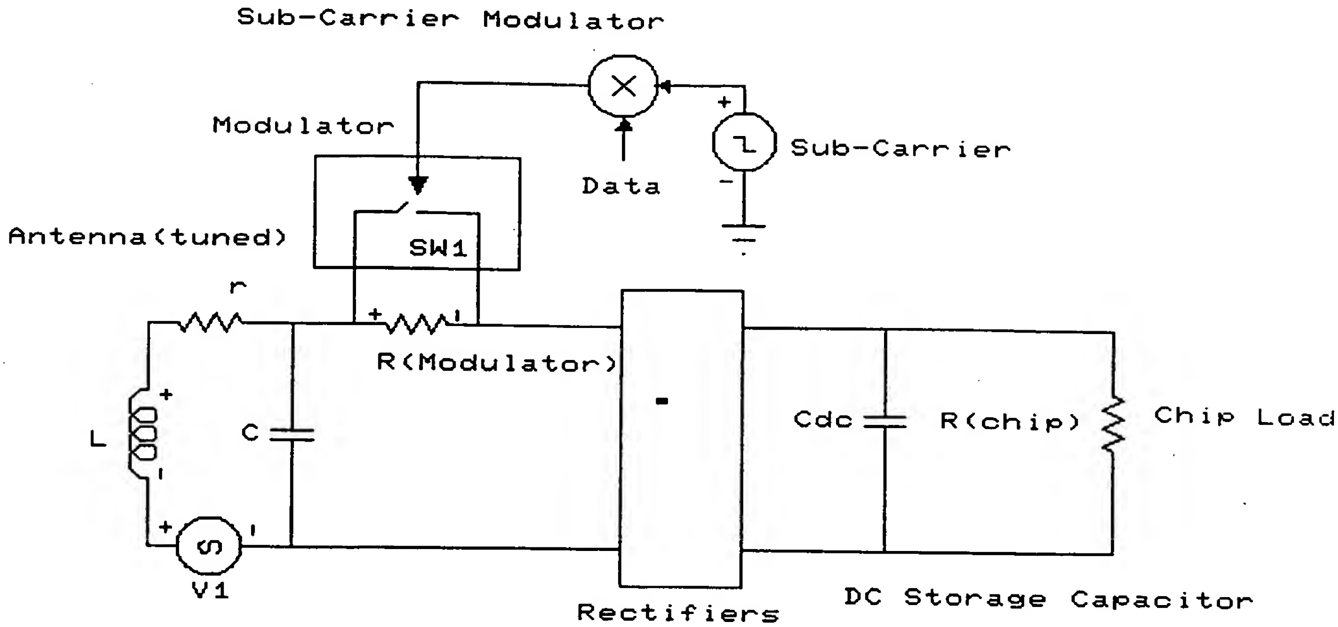



Figure 9(a) : Invention with Data Modulated onto Sub-Carrier with Modulator in AC Circuit

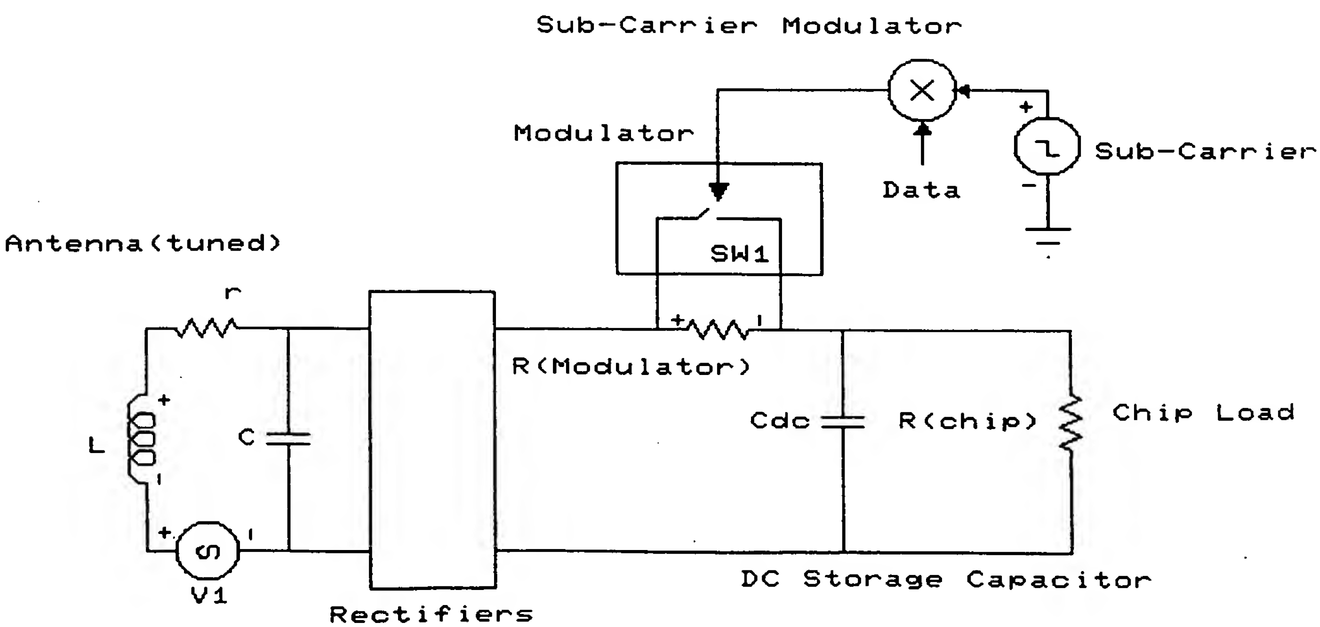



Figure 9(b) : Invention with Data Modulated onto Sub-Carrier with Modulator in DC Circuit

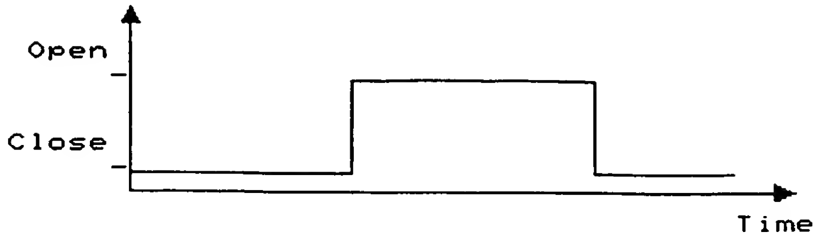



Figure 10(a) : Switch Function

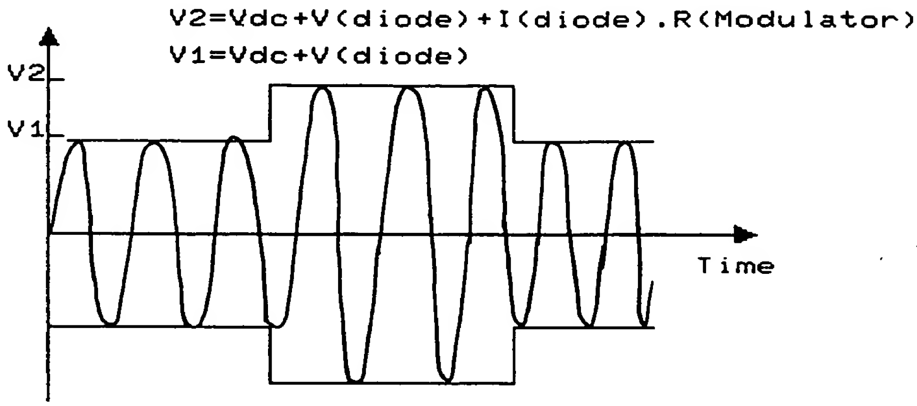



Figure 10(b) : Antenna Voltage


Figure 10(c) : Sub-Carrier Spectrum

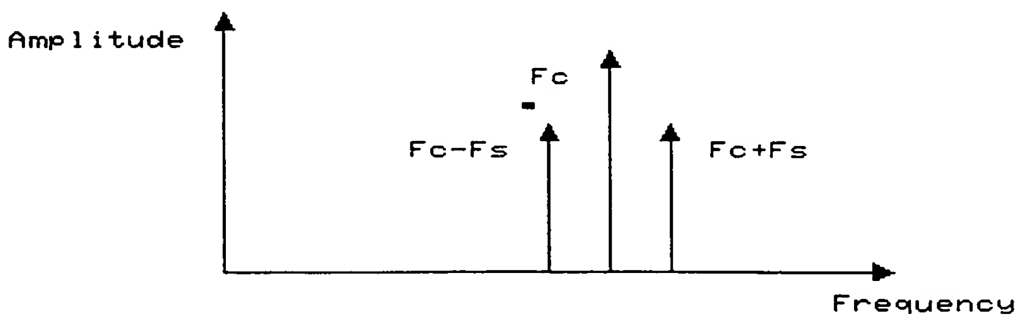



Figure 10(d) : Sub-Carrier Amplitude Modulation Sidebands

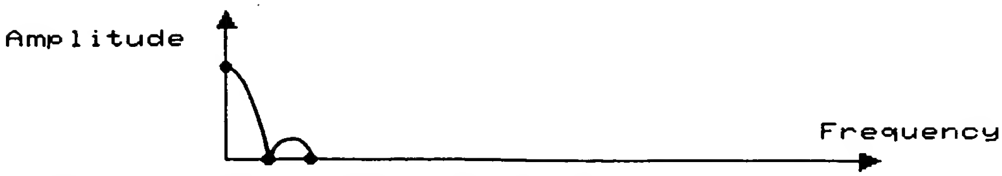



Figure 10(e) : Data Spectrum

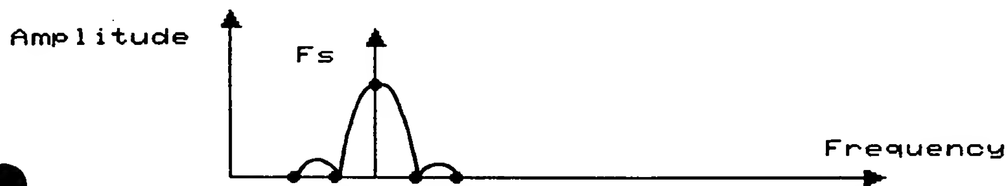



Figure 10(f) : Data Spectrum Modulated onto Sub-Carrier

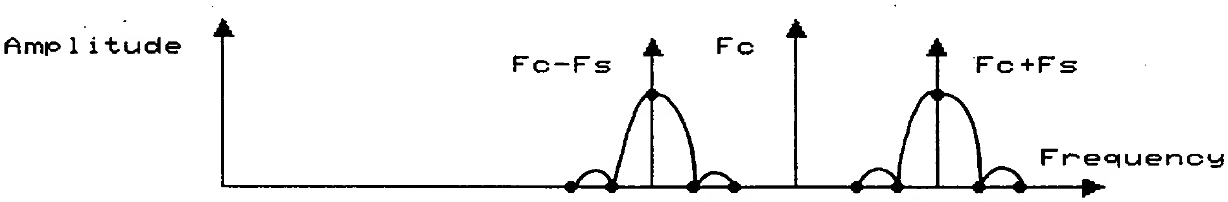



Figure 10(g) : Spectrum Data Modulated Sub-Carrier Amplitude Modulated onto Excitation Frequency

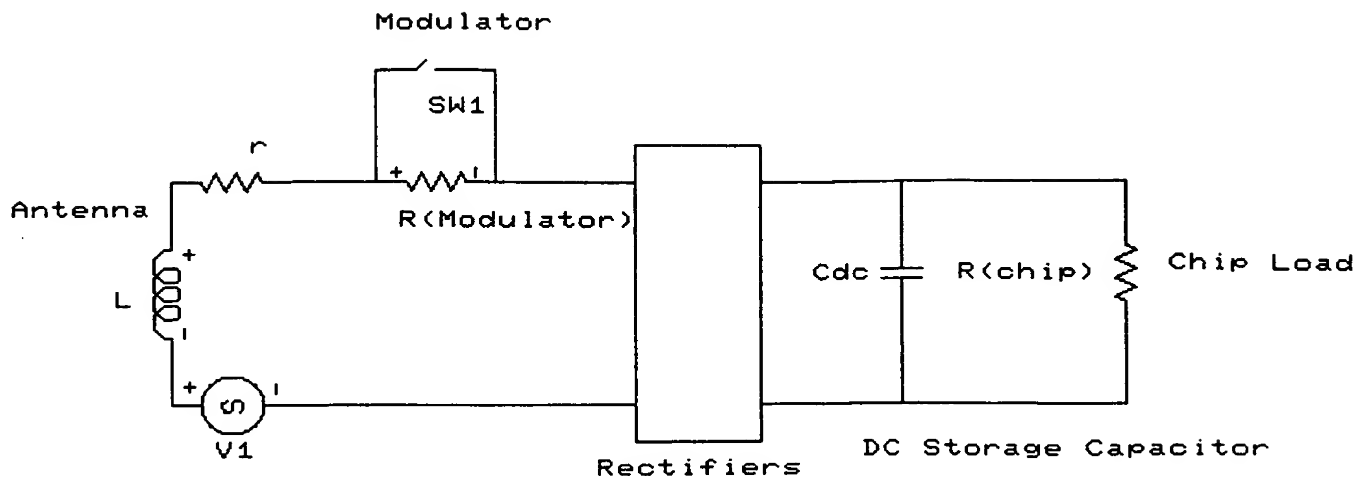



Figure 11(a): Invention with Modulator in AC part of Circuit where Antenna is Untuned

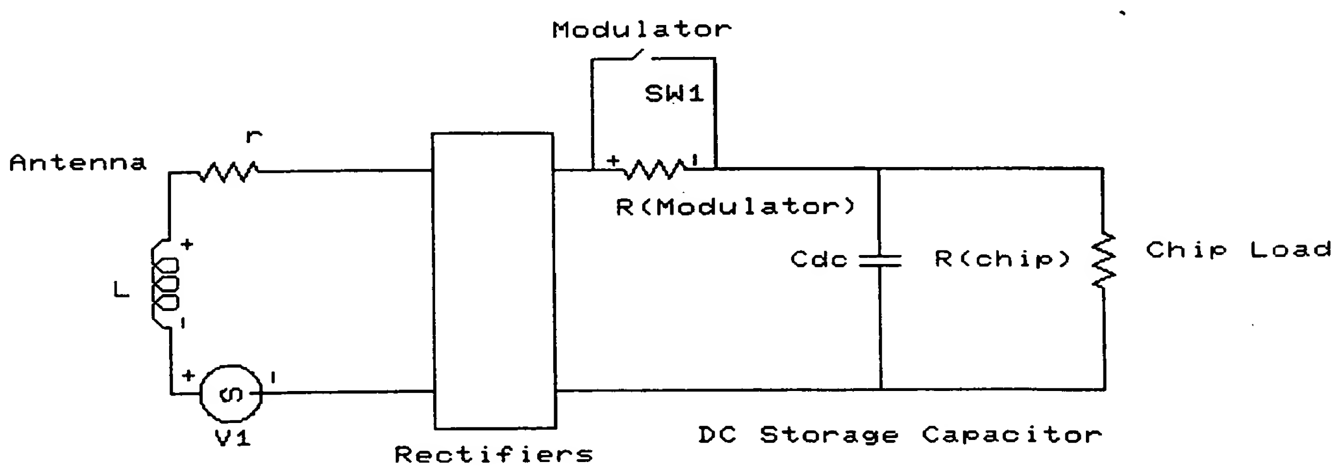



Figure 11(b): Invention with Modulator in DC part of Circuit where Antenna is Untuned

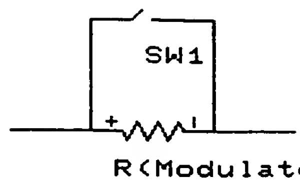



Figure 12(a) : Simple Switch Modulator

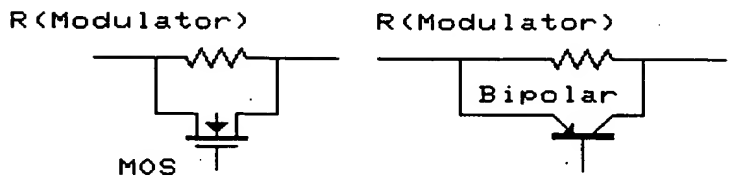



Figure 12(b) : Examples of Modulation Switches

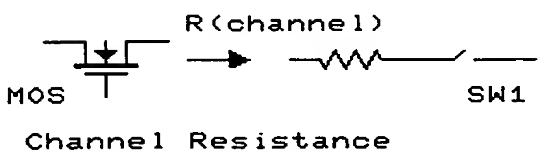



Figure 12(c) : Use of Channel Resistance to make Switchable Resistances

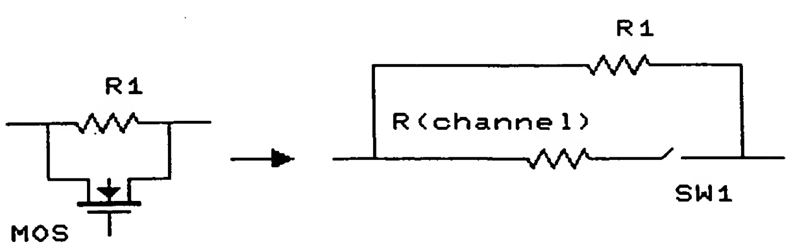



Figure 12(d) : Resistance varied between Two Values

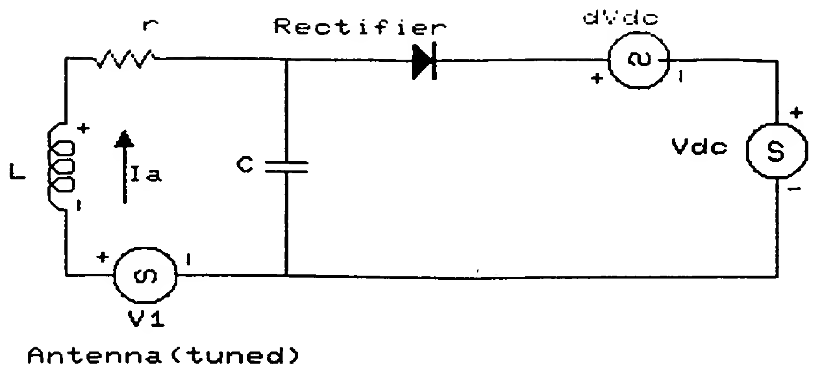



Figure 13(a): Electrical Model for Small change in DC Storage Voltage

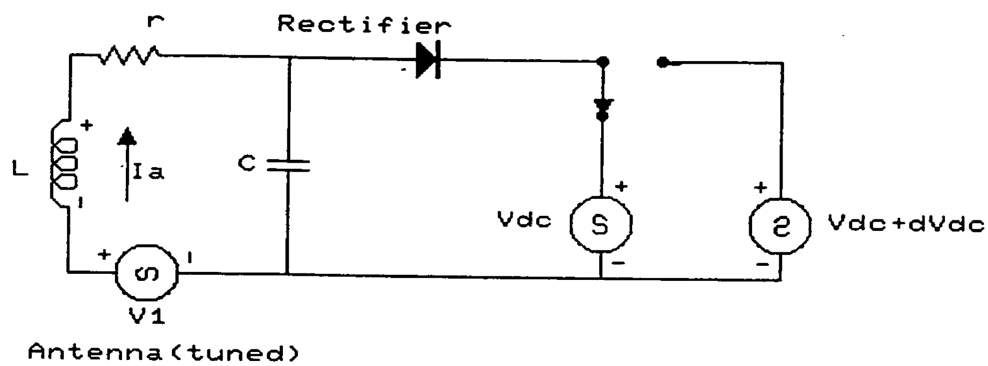



Figure 13(b): Electrical Model for Step Change in DC Voltage

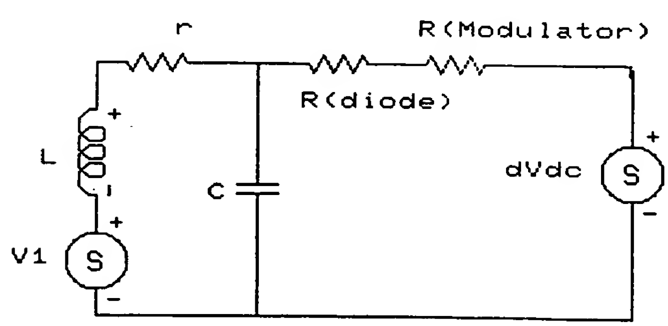



Figure 14 : Electrical Model for Compensation Theorem Derive Modulator